The APEX/EPOS Quandary: the Way Out via Low Energy Studies

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Abstract

A scorecard summary of the various data of the "Sharp Lepton Problem" is presented. The present situation, in which APEX reports "...no evidence for sharp pairs..." even as their data exhibits a sharp pair excess near 800 keV, is discussed. Two kinds of low energy experiments utilizing non-heavy ion processes are suggested as means to break the impasse arising from the ambiguity of the present heavy ion data.

1. Introduction

The history of the "Sharp Lepton Problem" (which is the "(e^+e^-) Puzzle" of the heavy ion pairs extended to include the sharp electrons observed in $(\beta^+ + \text{ATOM})$ collisons), exemplifies the difficulties in studying weak signals of unknown origin. Here one confronts data for which the physics we know offers no explanations whatsoever. This is not typical of one's customary research experience. Some react skeptically: if we don't understand it it must be spurious; others become enthused, and sometimes too uncritical. Meanwhile the scientific community in which we exist, like its individual members, also adopts shifting attitudes. Thus in the late 1980's pair research was at the top, and no effort or expense was beyond consideration. Now in the late 1990's, the community seems to want the whole field of sharp leptons simply to go away and be forgotten. Perhaps we need success more than we desire truth. Along with these very human vacillations, scientific standards seem also to bend. Sceptics are outcasts when enthusiasm reigns, and seers when the chill sets in. In the meanwhile working researchers must cling to their standards of objectivity, openess, and integrity, and strive against the emotional tides to base their judgements only upon the scientific evidence. In the end physics is grounded in empirical fact, and in the end the real physical truth will emerge.

In this spirit we present here a brief review of the Sharp Lepton data accumulated so far. We offer also a reinterpretation of the negative first results reported from the APEX experiment, which was proposed to settle the issue of the heavy ion sharp pairs once and for all. Sadly, its results are insufficient to that goal, but have been so misstated as to obscure that fact. In the end we emphasize the lepton and gamma alternatives to heavy ions for studing the Sharp Lepton Problem, and suggest that such cheap and

reproducible experiments may offer the escape from the quandary presented by the present ambiguity of the heavy ion data.

2. The Various Sharp Lepton Data

Table I lists the various classes of data relevant to the "Sharp Lepton Problem", viewed over the template of the Quadronium Scenario. Included are the sharp ($\Gamma \sim 80$keV) positrons, which first lead to the search for the very sharp ($\Gamma \leq 40$keV) ($e^+ e^-$) pairs. Independently, very very sharp ($\Gamma \leq 3$keV) electrons have been observed in collisions of beta decay positrons with high-Z U and Th atoms. Also listed are prospective Delbrück resonances, arising from creation of the $\{Q_0, Z\}$ molecular bound state in (γ, Z) processes upon high-Z elements. (Such bound states were envisaged already in the very earliest Q_0 phenomenology[1, 2] of the EPOS/I pairs from U + Ta collisions.) Finally the long standing 10σ discrepancy in the lifetime for the 3γ decay of orthopositronium is listed because it, among all of the high precision quantities of QED[3] should be especially sensitive to the bound state poles of the Q_0 particle, whose existence is the central hypothesis of the "Q_0 Phenomenology". If this discrepancy persists after the calculation of the next order QED correction to the lifetime has been completed, attention would then turn towards more non-conventional explanations, such as the existence of the bound Q_0 particle.

TABLE I: SCORECARD of SHARP LEPTON DATA					
Years	Collaboration:	EPOS/I	ORANGE	APEX	EPOS/II
'83-'86	H.I.Positrons	YES[4, 5]	YES[6]	-	-
'86-'96	H.I.Sharp Pairs	YES	YES	(NO)$\Rightarrow$YES	(NO)$\Rightarrow$(??)
	[References]	[7, 8, 9]	[10, 11, 12]	[13]; [14, 15]	[16];[17]
	Repeated?	YES[18]	-	-	-
'86-93	Sharp Electrons (from β^++Z):	YES[19]	NO[20]	NO[21]	YES[22]	YES[23]
	Thin? Repeat?	NO	NO	NO	NO	YES[24, 25, 26]
'95	Delbrück (γ,Z) $\sim$1.8 MeV:	YES;	(Zilges, et al.[27])		
	$\Gamma_{e+e-}/\Gamma_\gamma$:	???	(Key to distinguishing $\{Q_0, Z\}$ from nuclear IPC)		
	Ps$\rightarrow 3\gamma$ Decay:	Q_0 pole can explain Long Standing 10σ QED discrepancy			

Table I. The Various data relevant to the Sharp Lepton Problem are summarized. Although the most recent heavy ion experiments (APEX and EPOS/II) report no positive evidence for sharp pairs, both actually recorded positive signals, as discussed below, and neither can definitively exclude the lines reported earlier. The non-heavy ion data, which is accessible at lower cost and which may be more easily reproduced by independent experimenters, acquires special interest as the heavy ion efforts flag.

Of these data, those from the non-heavy ion processes of lepton and resonant photon scattering upon high-Z atoms are especially interesting since they are simple, cheap and

repeatable as the heavy ion studies are not. In particular, Sakai[24, 26] has repeatedly[1] reported very very sharp electron lines emerging from the irradiation of thin U and Th targets by positrons from energetic β^+ decays, with an estimated[3] cross section of ~100 mb. Within the Composite Q_0 Scenario, Sakai's data can be understood[28] as arising from a supercomposite molecular bound state, $\{Q_0, Z\}$, of the Q_0 atom to the nuclear Coulomb field. Such states would also appear as Delbrück resonances in photon scattering from high-Z nuclei, of the type recently observed by Zilges, et al.[27].

3. APEX' Bizarre Self-Contradiction

In their brief report[13] on their extended effort to settle the question of sharp pairs from high-Z heavy ion collisions, the APEX collaboration asserts unconditionally that "No evidence is found for sharp peaks in the present data." But the data plotted logarithmically in Figure 2 of their own report exhibit a sharp peak near 800 keV of precisely the type which APEX was seeking, and which they deny having found. We here discuss these matters briefly, and point out the erroneous assumption which may have misled APEX to expect more than was possible and thereby to overlook a result that was less than hoped for.
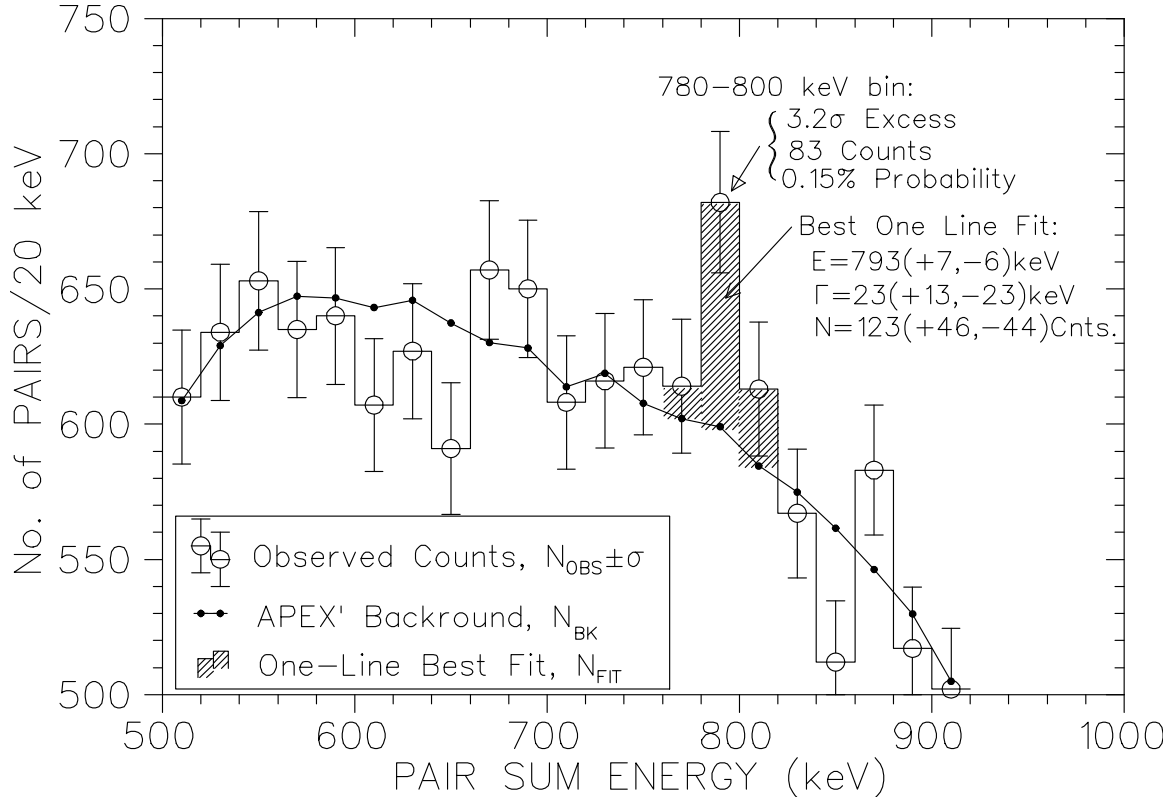

Fig.1. The APEX' data and the APEX' event-event mixed background published in Fig.2 of Ref.[13] are plotted. The one line best fit (shown shaded), and other statistical analyses of this data are discussed in the text.

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[1]As noted in Table I, two other experiments[19, 22] preceding those of Sakai, et al. have reported corroborating sharp lepton evidence, and two others[20, 21] report no such evidence. Only Sakai used thin targets.

The published APEX U +Th data and APEX' event mixed background are plotted in Fig.1 on a linear scale. A 3.2σ excess is clearly evident in the 780-800 keV bin. Such an excess is expected to occur as a fluctuation about once in 700 such single-bin measurements, or about once in 11 complete 60-bin APEX experiments.

Fig. 1 also shows our 4-parameter (Background plus One Sharp Line) best χ^2 fit[14, 15] near 800 keV. The best fitting line has an energy of 793, a width of 23keV, and a strength of 123±46 sharp pairs. APEX' 1-parameter (Background-Only) fit yields for the 60 APEX bins a χ^2_{59} value of 65.76; our 4-parameter (Background plus One Sharp Line) fit yields $\chi^2_{56} = 54.11$, a reduction of 11.65 in χ^2. The probability that the true χ^2 value exceeds these respective values increases from 25% to 55% when the sharp line is allowed,indicating a better quality of fit for the one-sharp line fit. Moreover, confidence level analysis of 1-bin, 2-bin and 3-bin groupings all imply that at the 99% confidence level there are more than 23 and less than 227 sharp pairs near 790 keV. The 99% CL lower bounds for groups not including the 790 keV bin are all negligible (smaller than 2 counts), indicating that at the 99% confidence level the APEX data provides evidence for excess sharp pairs *only* in the 790 keV bin.

However one wishes to assess the physical implications of this data, it is clearly not factually accurate to state, as the APEX report states, that "No evidence is found for sharp peaks in the present data". It is remarkable that besides APEX' making this assertion which seems to fly in the face of their own data, they also fail to provide any statistical analysis whatsoever which supports it.

3.1 APEX and EPOS/I Pair Databases are Comparable

Table II compares the APEX and EPOS/I experiments, and their respective sharp

TABLE II: COMPARE EPOS/I & APEX PAIR DATA, EFFICIENCIES			
	EPOS/I[9]	APEX[13, 29]	
PAIRS COUNTED			
TOTAL	-	126K	
RL(1,n), all n	-	80.1K	
RL(1,1): $(1e^+, 1e^-)$ Only	50K	40.8K	
RL(1,1) near 800 keV	1280	1480	..per 20 keV
Sharp Pairs near 800 keV	97±38	123±36	
Ratio: Sharp/Total RL(1,1)	97/50K	123/40.8K	
EFFICIENCIES			(Apex' Proposal)
positrons: ϵ_{e+}	10.4%	3.7%	9.0%
back to back pairs: $\epsilon_{180°}$	1.4%	1.3%	5.6%

Table II. By every quantitative measure, the APEX pair data base is, for the purpose of confronting EPOS/I's data, at best comparable to that of EPOS/I, and surely not significantly superior. Therefore, APEX' weak evidence for a sharp pair line near 800 keV, and its failure to reproduce the EPOS/I sharp pair line near 600 keV do not provide decisive evidence concerning the existence of sharp pairs.

pair counts near 800 keV. It shows that the APEX' 123 sharp pairs among its 40.8K background pairs of EPOS' RL(1,1) type is roughly commensurate with the EPOS' count of ∼100 sharp pairs among a total of 50K background pairs: Thus, APEX' ∼100 sharp pair count is roughly what they should have expected from the EPOS experiment.

But in fact APEX' published expectation (in Fig. 2 of Ref.[13]) was much greater: ∼2500 sharp pairs near 800 keV. We analyze both experiments in detail in Ref.[14, 15], and conclude that APEX expectations are 9.3× too large because of their unsupported, and unsupportable, assumption that the sharp pair cross section was 5.0μb/sr and constant, independent of energy.

3.2 How APEX' Expectations Were Inflated

Actually, the EPOS/I paper presented[9] definite if incomplete, evidence for an energy dependent sharp pair production process, and offered the 5.0μb/sr value only as an order of magnitude for an unspecified "maximal" cross section. The APEX' constant 5.0μb/sr assumption can therefore not be justified by the EPOS/I results, or even semantically by the EPOS/I's literal statements.
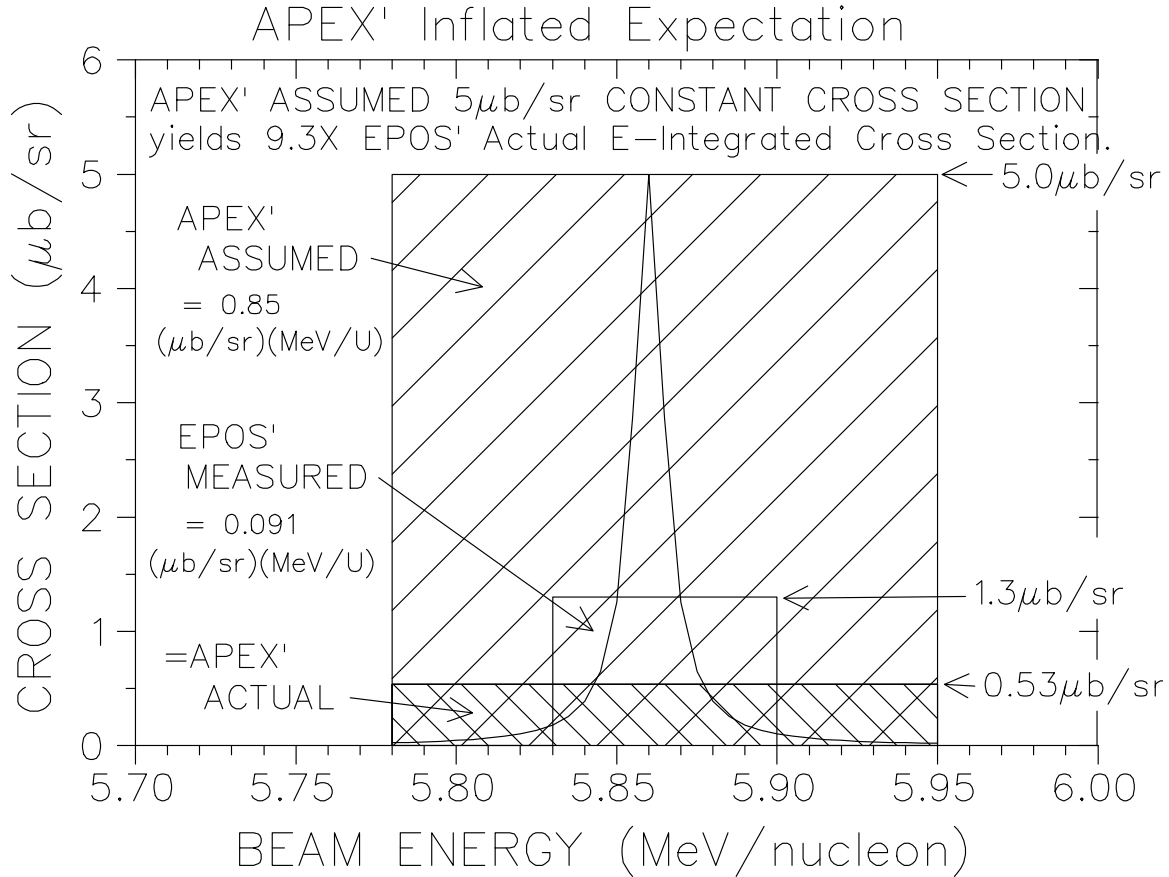

Fig. 2 APEX' analysis assumed a constant 5.0μb/sr sharp pair production cross section, which yields an energy integrated cross section given by the cross hatched area of the figure. This is almost an order of magnitude larger than the value set by EPOS/I's ∼100 measured counts.

For a Breit Wigner energy dependence, the EPOS/I sharp pair data implies no unique value for the sharp pair cross section at all, but rather a value for the *energy integrated cross section*, which must be about 0.091(μb/sr)(MeV/nucleon) in order to yield EPOS/I's ~100 observed sharp pairs. If its maximal value were 5.0μb/sr, this cross section would have a width of about 0.02 (MeV/nucleon). Such a dependence is sketched in Fig. 2. For each different APEX and EPOS/I beam spread, the specifically appropriate average pair cross section must be defined to yield this correct energy integrated value.

Fig. 2 also exhibits the average cross section of 1.3(μb/sr) (Cf. Ref.[16]), appropriate for the EPOS/I beam energy spread of 0.07(MeV/nucleon), and the value, 0.53(μb/sr),appropriate to APEX' thicker target beam energy spread of 0.17(MeV/nucleon). This latter value, 9.3$\times$ smaller than APEX' assumed 5.0μb/sr, is the average cross section which EPOS/I's data actually implies for the APEX experiment. In contrast, APEX' unsupportable 5.0μb/sr assumption implies the much larger energy-integrated cross section of 5.0*0.17 = 0.85(μb/sr)(MeV/nucleon), indicated in Fig.2 by the cross hatching, larger than the actual value by the same factor of 9.3. Instead of ~2500 pairs, APEX ought to have been expecting ~270; APEX' experiment actually counted 123$\pm$46..

3.3 EPOS/II Observed 809 keV Line

Remarkably, the EPOS/II collaboration, which also claims no sharp pair signal in the only brief report[16] published so far, reports elsewhere (in Fig. 6.11 of Ref.[17]) a sharp excess of pairs at 609 kev, under the same selection conditions as were used by EPOS/I. Since this is precisely the energy of a line reported earlier by EPOS/I[9], the failure to discuss this observation in detail in Ref.[16] is an omission which one hopes will be rectified in a later publication.

4. Non-Heavy Ion Alternative Studies

In Table I, the evidence of Erb et al.[19], Bargholz, et al.[22], and Sakai, et al.[23], that leptons of sharp energy emerge from collisions of few MeV positrons with high-Z atoms opens an experimental window upon the Sharp Lepton Problem which is alternative to studies with high-Z heavy ion collisions. Since all of Sakai's studies have been carried out with positrons whose energy distribution is set by his energetic β emitters, they provide no evidence as to which positron energies are most effective in their production. It is therefore a matter of urgency to verify the Sakai phenomenon with beams of leptons whose energy is well-controlled.

4.1 Q_0 Spotlights 4-Lepton Box Diagrams in QED

The Quadronium Scenario hangs upon the assumption that the four lepton ($e^+e^+e^-e^-$) system is strongly (relativistically !) bound. The resulting effect upon QED is portrayed in Fig. 3, which shows that if Q_0 has bound states, then any QED diagram which contains a 4-lepton "box" diagram requires that the corresponding integration over the 4-lepton continuum must be corrected by the addition of a pole term from each such bound state, as diagrammed in Fig. 3(c).

It is obvious from Fig.3 that light upon light scattering will be a resonant process when the Quantum numbers of the two photons are equal to those of an eigenstate of Q_0. Then it also follows that Delbrück scattering (in which two of the photons of Fig 3(b) or Fig 3(c) are replaced by Coulomb interactions with a nuclear Coulomb field), will also exhibit resonances at incoming photon energies equal to to an eigenenergy of the $\{Q_0,Z\}$ supercomposite bound system, given by a sharp pair sum energy less the (small[2]) $\{Q_0,Z\}$ binding energy. If only one (presumably an s-state) state of $\{Q_0,Z\}$ is bound, then resonance will have the spin and parity, $(J\pi)$ of the Q_0 eigenstate. Then when the Q_0 state has $(J\pi) = (1^-)$ the excitation of the resonance will be favored; other multipoles will be excited only with reduced amplitudes.
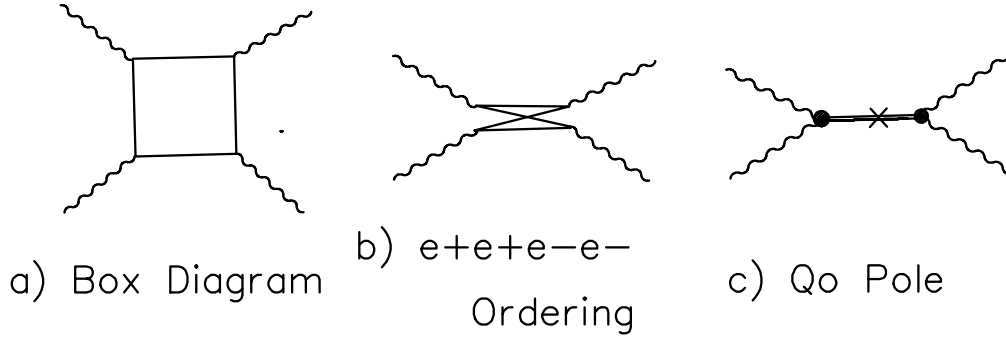
FERMI BOX SUBDIAGRAMS AND Qo POLES

a) Box Diagram   b) e+e+e−e− Ordering   c) Qo Pole

Fig.3. (a) The generic four–Fermi box subdiagram of QED; (b) The $(e^+e^+e^-e^-)$ time-ordering of the Fermi box; (c) The Q_0 –pole, which provides a pole correction to (b)for each bound state.

4.2 Delbrück Scattering Resonances and Q_0

Indeed, three resonances have already been observed[27] near 1.8 MeV in (γ, U) scattering, and have been interpreted as conventional nuclear excited states in the U target. But in the Quandronium Scenario, any one of them may be due to a $\{Q_0,U\}$ bound state rather than a nuclear state. How is one to ascertain the difference?

One qualitative distinction is expected to be the branching ratio of the decay by pair emission as compared to the decay by photon emission. Nuclear (1^-) excitations decay to the ground state by emitting a photon, which if sufficiently energetic may occasionaly produce a pair. Q_0, on the other hand, is most likely to decay to $(e^+e^-\gamma)$, yielding an (e^+e^-) pair of the total energy when the decay photon is replaced by a Coulomb interaction with the nuclear charge. Thus one expects pair emission to be dominant for the $\{Q_0,U\}$ bound state, and photon emission for the nuclear excited state. It is for this reason that the need for branching ratio evidence is emphasized in the Data Scorecard in Table I. Additionally, the $\{Q_0,U\}$ bound state energy, in constrast with a nuclear

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[2] As the phenomenolgy[1] of the U+Ta data indicates it to be.

excitation, should be essentially independent of neutron number of the nucleus, Z.

4.3 Delbrück Q_0 Creation and Sakai's Sharp Electrons

The incoming photon of the Delbrück scattering can also be delivered (virtually) to the atom in a bremsstrahlung scattering of a lepton, as, e.g., in Sakai's positron irradiation. Then the graphs of Fig.4(c) are the relevant ones. When the Q_0 is created bound to the nucleus the compound ssystem, because of the large mass of the nucleus, is essentially at rest in the laboratory frame of the target.

Qo CREATION IN COULOMB FIELD

RESONANTLY: AND AS BREHMSSTRAHLUNG:

a) via (Q$_o$e+e−γ) vertex, and b) via (Q$_o$γγ) vertex;   c) via γγ vertex.
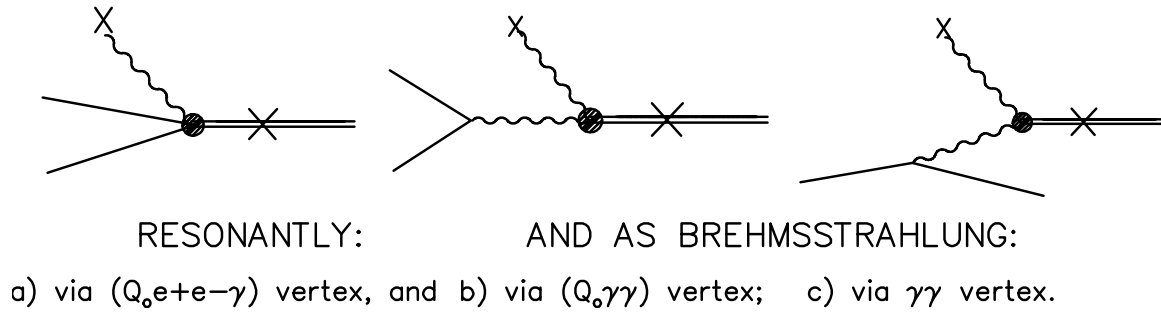
Fig.4. Q_0 creation by leptons can also occur by replacing the incoming photon of Delbrück scattering process by a bremsstrahlung photon from a scattered lepton as in Fig.4(c). (In addition the resonant processes diagrammed in (a) and (b) may occur when an incoming positron of the correct energy correlates or annihilates, respectively, with one of the atomic electrons.)

One might therefore think that this situation is made to order to explain also Sakai's very very sharp electrons, whose width requires a source source stringently at rest (i.e., with a a kinetic energy for the Q_0 source particle of less than 3 eV) in the lab frame. But that is incorrect, because the pair emitted from a bound $\{Q_0, Z\}$ state will exhibit the same effects of the nuclear Coulomb field as have already been described and observed in the EPOS/I 's U+Ta data[8, 9, 1, 2]; namely, a $\pm$ shifts of $\sim 10^2$ keV in the separate positron/electron energies which shifts vary with the distance of the decaying Q_0 from the nucleus. The latter property is crucial here, because it generates spreads in the separate lepton energies of the order of 10^2 keV, which preclude its providing Sakai's narrow (≤ 3 keV) electron lines.

How then can a scattering process create a Q_0 particle at rest in the lab, even when it is stipulated that a resonant bound state of $\{Q_0, Z\}$ is available? One naturally thinks of those events which lead to slightly unbound $\{Q_0, Z\}$ states which can break up and release Q_0, later to decay far from the nucleus. But these too provide an insufficient explanation: in the breakup process, the light Q_0 acquires essentially all of the breakup energy as kinetic energy. Then only states within a few eV (NOT keV!) of the breakup threshhold could produce such sharp pairs as Sakai observes.

4.4 Sakai's Electrons Stretch the Q_0 Scenario to Its Limit

One needs more: a mechanism for the emerging Q_0 to get rid of its kinetic energy as it separates from the nucleus, so that it can come to rest at a point outside of the nuclear Coulomb field. Remarkably, the Q_0 Scenario can provide[28] such a process, the "Viscous Breakup" of the slightly unbound $\{Q_0, Z\}$ state. In this process the Q_0, passes through the electron cloud of the U atom, =600fm to 7*7ao/92= 3X10+4 fm, where ao fm.... $\sim 3X10^4$ fm. delivering its kinetic energy into excitation energy of the atomic electrons, and emerging from the atom, (and therefore from the volume where the screened nuclear Coulomb field is non-zero), with a negligible velocity.

Such a description requires phenomena which exploit each of the four distinct length scales of the Q_0 Scenario: the nuclear (~ 10 fm), Q_0 (Radius = Compton wavelength, $\sim 10^2$ fm), Supercomposite Bound State (Radius, $R_o \sim 10^3$ fm), and the Bohr radii scale ($\sim 10^4$ fm) of high-Z atoms. In this way, the explanation of the Sakai pairs pushes the Q_0 Scenario perhaps to it very limits.

Some may view this unfavorably, recoiling against such a "stretching" of the hypothesis' possibilities. To the contrary, we insist that although two alternative phenomenologies are always preferable to one phenomenology, one phenomenology is infinitely better than none at all. Since we here face this array of Sharp Lepton data which we know how to summarize under only one phenomenology, the Q_0 Scenario, we are obliged to explore all of its possibilities, searching both for a killer datum which it cannot encompass, and for predictive implications which can be tested in new experiments.

For the Sakai sharp lines this procees succeeds wonderfully: The Sakai lines do not contradict the Q_0 Scenario, but instead provide two very specific verifiable inferences: (a) that each sharp Sakai electron accompanies a partner positron which has the same narrow energy distribution; (b) that (because the diagrams of Fig.4(c) are indifferent to the charge sign of the scattered lepton) Sakai's sharp electrons should be found not only in collisions of positrons with high-Z atoms, but also of electrons upon the same elements, and with the same cross section as for the electrons.

5. Recommendation: Study e$^-$'s + (U, or Th)

The outcome is the prediction that beams of few MeV electrons upon U and Th atoms should produce sharp *positrons* (the decay partners of Sakai's sharp electrons) of energy 330.1 keV and width ≤ 3 keV, with a cross section of about 100 mb. Such an experiment will have large electron backgrounds, analogous to the large positron backgrounds of Sakai's β^+ iradiations, but its positrons arise only from pair production and Q_0 decay. Since Sakai's positrons eject many electron from the target atoms, requiring his sharp electrons had to be observed above a large electron background, the electron beam experiment promises a smaller positron background to the sharp positron line being sought than was Sakai's electron background to his sharp electron lines.

6. Summary and Conclusions

A crucial feature of the Q_0 Scenario is its ability to unify certain non-heavy ion processes with the "(e^+e^-) Puzzle" posed by the heavy ion data. Here it recommends the study of few MeV electron scattering from high-Z atoms, and of the branching ratios for the decay of Delbrück resonances in high-Z atoms.

These non-heavy ion alternatives are essential in view of the present impasse arising from the failure of the recent (APEX and EPOS/II) heavy ion experiments to corroborate or to definitively exclude the earlier (EPOS/I and Orange) reports of sharp pair lines.

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